A STUDY OF THE NAVICULAR IN THE HUMAN AND ANTHROPOID FOOT.

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OF the bones of the human foot the navicular is perhaps the most interesting. For this there are various reasons, morphological, mechanical, or both.

In the first place, the bone consists of two components, a body which is a true tarsal element and corresponds to the centrale of the lower vertebrates, and a tuberosity which, as regards its morphology, is doubtful, and not infrequently is separate in its ossification.

Secondly, as an outcome of its cartilaginous state during the first five or six years of life, the navicular, whilst in a plastic state, is subjected to the tension and strain of the structures attached to it, and to the pressure transmitted to it from its neighbours. In consequence, it is moulded into shapes more diverse than those of any other tarsal element.

Lastly, it presents an interesting contrast to its homologue in the upper limb. As a result of its position near the summit of the arch of the foot, of its situation just in front of the transverse tarsal joint, from the fact that it is late (comparatively) in its ossification, and at the same time gives attachment to a powerful muscle, the bone is bold in outline and fairly massive in conformation. Its homologue in the human manus is insignificant in size and contour, and its separate existence is transitory.

The specimens which I was able to examine (about 600 in number were from the collection of Egyptian bones in the possession of Professor Macalister. It was at his incentive that this paper was written, and I take this opportunity of thanking him for permitting access to his rich store of material, and for many kind suggestions.

I must also thank Dr Duckworth for allowing me to describe the anthropoid navicular bones in his possession.

I am much indebted to Miss Elizabeth Dale for the care she has taken in making the drawings from which the illustrations were prepared.

Nomenclature.

The names which I have chosen for the bone and its surfaces are mostly modifications of those agreed upon by the Basel Convention, together with some of the terms introduced by Professor Pfitzner in his brilliant and laborious paper on the bones of the foot.

I have described the bone as consisting of a chief part or corpus—the os naviculare, which corresponds to the centrale of lower vertebrates—and a tuberosity (tuberositas ossis navicularis) whose nature is unsettled. To the latter of these components an additional element, the tibiale externum, may be added, as Professor Pfitzner has pointed out.

The names in use for some of the surfaces in most English text-books are not in all cases quite accurate. For instance, since the long axis of the bone is oblique rather than horizontal, it is better to call the superior surface dorsal, and subdivide it according to the direction in which its two portions look; and the inferior, plantar, since neither of these surfaces looks exactly in the direction indicated by the names —superior and inferior.

Again, the so-called external surface, which faces the cuboid, is directed as much downwards as outwards—facies lateralis or facies cuboidea is therefore, perhaps, a better name.

The names which I have adopted are as follows :—

Nomenclature formed on the model of the Basel Convention.	Nomenclature employed by Professor Pfitzner.	Nomenclature in use in England.
Os naviculare.	Naviculare.	Navicular or scaphoid bone.
Processus plantaris.	Cuboides secundarium, also fibulo-plantar corner and lateral plantar process.	Inferior navicular tubercle (Barclay-Smith) or plantar point.
Tuberositas ossis navicularis.	Tuberositas ossis navicularis.	Tuberosity.
	Tibiale externum.	Sesamoid bone in the tendon of the tibialis posticus.

Os Naviculare.

Surfaces.

Facies articularis posterior.	Facies articularis posterior, or facet for caput tali.	Posterior or astragalar surface.
	Facies articularis posterior accessoria. This is that part of the facet for caput tali contributed by Pfitzner's cuboides secundarium.	This would correspond to that portion of the astragalar surface contributed by a large plantar point.

Nomenclature formed on the model of the Basel Convention.	Nomenclature employed by Professor Pfitzner.	Nomenclature in use in England.	
Facies articularis anterior.	Facies articularis anterior medialis, or articulatio cuneo-navicularis I.	The anterior surface for the internal, middle and external cuneiform bones.	
	Facies articularis anterior media, or articulatio cuneo-navicularis II.		
	Facies articularis anterior lateralis, or articulatio cuneo-navicularis III.		
	Facies anterior intermedia. This is an occasional facet for the dorsal part of cuneiforme I. bipartitum.	An occasional facet for the dorsal part of the internal cuneiform.	
Facies dorsalis superior.		Superior surface.	
Facies dorsalis medialis.			
Facies plantaris.		Inferior surface.	
Facies lateralis.	Facies articularis lateralis anterior, or articulatio cubo-navicularis.	Cuboid facet.	These, together with the non-articular part, constitute the external surface.
	Facies articularis lateralis posterior, or articulatio calcaneo-navicularis.	Occasional calcaneal facet.	

TUBEROSITAS OSSIS NAVICULARIS.

Surfaces.

	Facies articularis inferior, which is an occasional facet for the tibiale externum.	Facet for sesamoid bone in tibialis posticus.
	Facies articularis tuberositatis.	Occasional facet for astragalus.
Facies anterior.		This is continuous with the anterior surface for the cuneiform bones.

Nomenclature formed on the model of the Basel Convention.	Nomenclature employed by Professor Pfitzner.	Nomenclature in use in England.
Facies dorsalis.		This is a continuation of the dorsal surface of the body.
Facies plantaris lateralis.		This is continuous with the plantar surface of the body.
Facies plantaris inferior.		This joins the last two of the above surfaces. It forms the inner and under surface of the tuberosity, *i.e.* the "inner end of it'

The Os Naviculare.

Facies Articularis Posterior, or Astragalar Surface. (Figs. 1 to 5.)

The whole of this surface is occupied by the caput tali, and as a rule the caput is confined to this area. In some cases, however, the caput also articulates with the tuberosity.

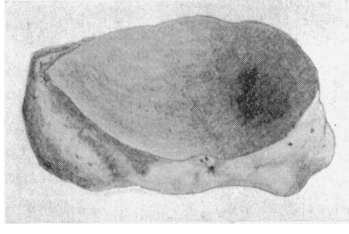

Fig. 1 —Almost oval.

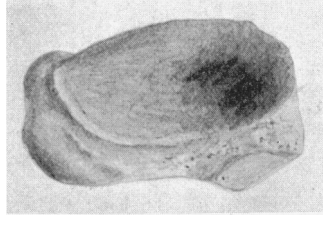

Fig. 2. —Egg-shaped.

The shape of the facet.—The facet for the caput tali is generally referred to in English text-books as a large oval, concave facet. Pfitzner figures two types of surface, a quadrilateral and an egg-shaped, corresponding to the two types of ground-plan of the navicular which he describes, *i.e.* a cuboidal and an egg-shaped.

In none of the specimens examined by me is the astragalar facet a perfect oval. It approaches the oval, however, in 33 (fig 1). It is egg-shaped in 85 (fig. 2). In most cases, however (434), it is pear-shaped (fig. 3) In the last two varieties the narrow end of the egg or pear is directed towards the tuberosity. Sometimes (10) it is almost quadrilateral, occasionally (4) triangular (figs. 4 and 5).

In many of the above specimens, the facet described as pear-shaped

might perhaps have been classed as quadrilateral; it is, however, never absolutely so. Even when the plantar point (fibulo-plantar angle) is prominent and forms, like the apex of the pear (tibio-plantar angle), a distinct angle, there is rarely an angle at the fibulo-dorsal end, and never one at the tibio-dorsal end of the facet (*i.e.* the two ends of the base of the pear). The margo dorsalis posterior forms one curved border, therefore, in

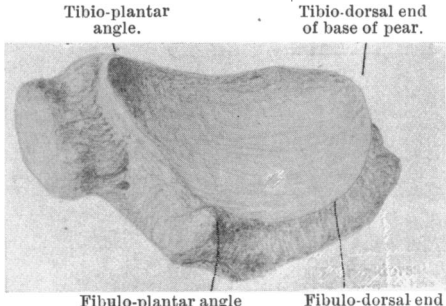

FIG. 3.—Pear-shaped.

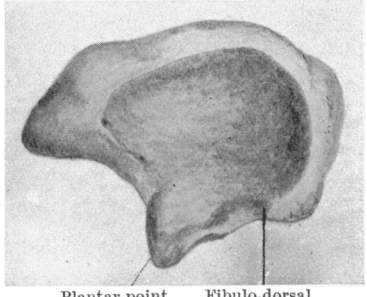

FIG. 4.—Almost quadrilateral.

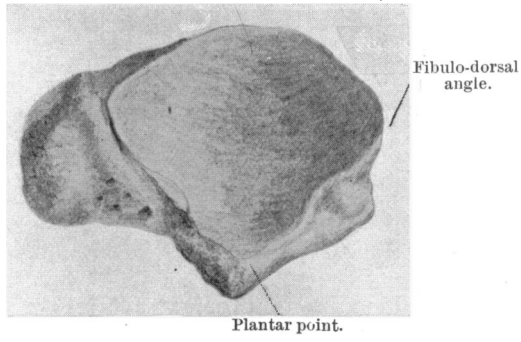

FIG. 5.—Triangular.

all cases. In those rare cases in which there is a fibulo-dorsal angle, either the almost quadrilateral type of facet is present, or, when the margo dorsalis posterior is very short, the whole facet is triangular, with its apex at the plantar point and its base formed by the gently curved margo dorsalis posterior (figs. 4 and 5).

According to Pfitzner, the difference in the ground-form of the navicular, and consequently the difference in the shape of the surface for the caput tali, depends upon the absence or presence of the lateral plantar

process or plantar point; in the first case, we have the egg-shaped, in the second the cuboidal, ground-plan.

He states that the projection of this part of the bone must at once arouse the suspicion that we are dealing with an inconstant, originally independent part of the skeleton, and that this portion of the navicular, in reality, is formed by the assimilation of an inconstant tarsal, namely, what he calls cuboides secundarium. If this be so, however, we should expect the process to remain separate in some cases. In none of the specimens which I examined did I find the plantar point existing as a separate ossicle, but in one I found a trace of a suture on the facies articularis posterior and facies lateralis articularis anterior (cubo-navicular articulation). The facet for the cuboid was subdivided by a groove into two facets; the groove was continuous with the suture on the astragalar surface.

Gruber mentions three similar cases, and Pfitzner conjectures that this arrangement indicates a separation of the joint between the navicular and cuboid from that between cuboides secundarium and cuboid.

The large size of this process, however, in the cuboidal type of bone can be explained equally well mechanically as morphologically. It must be remembered, in dealing with this bone, that it is later in its ossification than any of the other tarsal bones, and that the child is walking from about the second to the fifth year with its navicular in a cartilaginous condition. During this period, the inferior calcaneo-navicular ligament is exerting traction on the plantar point, and in this way, supposing the bone ossifies late, and the child is particularly active, the point might easily be drawn out into a prominent process. Its nipple-like appearance in many cases certainly suggests this mode of origin. If, on the other hand, this point is the representative of a separate tarsal element, the tension of the above ligament, by keeping up frequent movement during the early years of childhood, ought certainly, in some cases, to perpetuate the separate existence of this part of the bone, and we should therefore expect to find it occasionally as an independent ossicle, as is sometimes the case with the tuberosity. As stated above, however, and as Pfitzner admits, it has never been found as a separate ossicle in man. For the decisive answer to this question, Pfitzner observes that we must look to embryology. Until an enormous number of fœtal tarsi have been examined, the question as to whether this process is a separate element or not cannot be set at rest; but it is significant that the cartilage is a single continuous mass apparently chondrifying from a single centre. Though Gruber's three cases, and my own mentioned above, certainly lend support to Pfitzner's theory that the plantar point is the representative of a

separate tarsal element, at present the evidence is too meagre to warrant us in accepting Pfitzner's view.

The plantar point is well developed in most cases; very small in some of the specimens, and in a few absent. There are two types of plantar point—(*a*) the spur-like or nipple-like, (*b*) the rounded. It was spur-like or nipple-like in 318 specimens, and rounded in 134. It appears to be better developed in these ancient bones than in modern specimens.

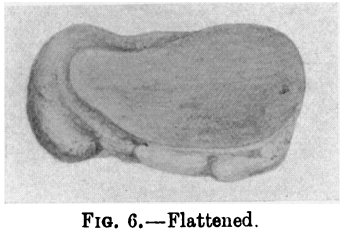

FIG. 6.—Flattened.

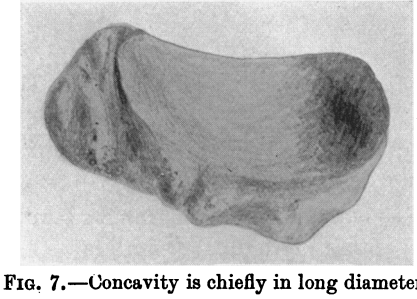

FIG. 7.—Concavity is chiefly in long diameter.

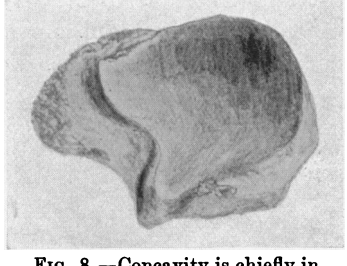

FIG. 8.—Concavity is chiefly in shorter diameter.

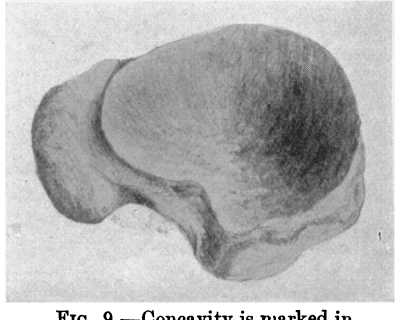

FIG. 9.—Concavity is marked in both diameters.

Since the point gives attachment to the inferior calcaneo-navicular ligament, we should expect it to vary directly in size with the development of this ligament. The process, when well developed, may encroach upon the facies articularis posterior, and help the inferior calcaneo-navicular ligament to support the head of the talus, extending beneath that structure in a bracket-like manner, and at the same time deepening the articulation.

The Nature and Depth of the Concavity. (Figs. 6 to 9.)

This varies considerably in different specimens. In a few cases it is almost absent, the facies articularis posterior being nearly flat. There are two types of concavity:—

(*a*) That with an increase of the concavity in the long diameter, which depends upon the extent of projection backwards of the upper and outer part of the margo dorsalis posterior (the margin of the broad end of the pear-shaped facet for caput tali), since the tibio-plantar angle (narrow end of the pear) projects considerably backwards in nearly all cases.

(*b*) That with an increase of the concavity in the shorter diameter, which, in turn, depends upon the projection towards the posterior surface of the plantar point.

When the concavity was especially deep, the increase in most cases (238) was in the longer diameter only, in the shorter diameter only in 55, in both diameters in 82. It is interesting to compare the type of concavity in man with that existing in the Simiidæ (fig. 18). In all four genera the depth of the concavity is chiefly in the long diameter, and the plantar point does not extend towards the facies articularis posterior, but is small, and is confined to the facies plantaris. Since movement at the astragalo navicular joint in the Simiidæ is especially free, the view is rather suggested that a deeply concave surface for caput tali, in the long diameter, in man, is also correlated with great freedom of movement in a lateral direction at the same joint, and dislocation is thereby prevented during the side-to-side movement. The depth of concavity in the shorter diameter, as in the above 55 cases, since it is dependent chiefly on the projection of the plantar point, and is not found in the Simiidæ, is possibly correlated in man with a high and stable tarsal arch.

Anterior Surface. Facies Articularis Anterior. (Figs. 10, 11, and 12.)

Usual description: "Is furnished with a semilunar articular area which is subdivided by two faint ridges into three wedge-shaped facets" (Cunningham). "An oblong-shaped anterior surface, convex, and divided by two vertical ridges into three facets" (Morris). "It presents anteriorly a convex surface divided by two lines converging below into three facets" (Quain).

First, as to the shape of the whole surface. Cunningham's description is the most accurate; the surface is semilunar. The concavity of the half-moon is directed towards the plantar aspect. Secondly, as to the shape of the individual facets. The innermost, for the internal cuneiform, is more or less wedge-shaped, with the apex of the wedge directed towards the tuberosity; the middle facet is also wedge-shaped, with a truncated apex towards the plantar surface; the outermost facet is also a very blunt wedge in many cases, with the narrow end pointing, as a rule, towards the cuboidal facet.

Articulatio Cuneo-navicularis I.

The Facet for Internal Cuneiform. (Figs. 10 and 12.)

There are two chief types of surface; in the majority (393), the dorsal and plantar borders are on the same vertical level, or the dorsal border is only slightly more projecting than the plantar. In 187 specimens there is a shelving away of this surface towards the plantar aspect of the foot and in the direction of the tuberosity. In addition, the internal cuneiform

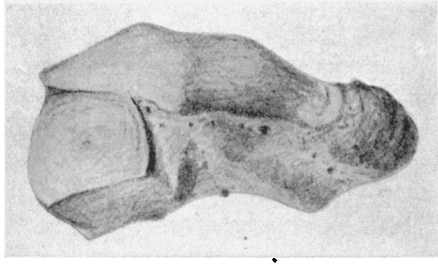

Fig. 10. —Gorilla.

Fig. 11.—Chimpanzee.

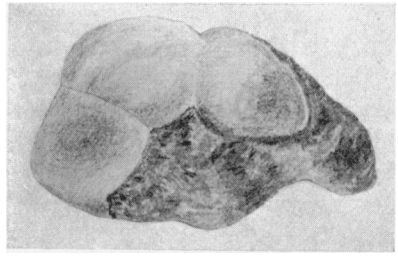

Fig. 12.—Man.

The figures 10 and 11 show the quadrilateral, concave facet for external cuneiform which is present in all the Simiidæ. Fig. 12 shows a similar facet which occurs sometimes in man. Figs. 10 and 12 also show the ridge or slight eminence on the facet for the internal cuneiform.

facet has often (170) a very slight vertical or oblique ridge, or eminence, about its middle (figs. 10 and 12). In some cases the ridge or eminence is so strongly developed as to subdivide this surface into two almost equal parts. This ridge probably marks the junction of two components, plantar and dorsal, of the internal cuneiform, which may, in some cases, remain separate. Pfitzner found two surfaces on the navicular at this joint in ten specimens. In those cases where the above eminence is especially well developed, and accompanied by the above-mentioned shelving away of the surface, the internal cuneiform facet is directed very obliquely, its surface

looking somewhat downwards. This will have a tendency to throw the internal cuneiform, and through it the big toe, plantarwards. This is probably correlated with greater freedom of flexion of the hallux, which would be expected in a non-boot-wearing people.

Articulatio Cuneo-navicularis II.

The Facet for the Middle Cuneiform.

This is also wedge-shaped in most cases, in one triangular; the apex points towards the plantar surface.

The surface is either flattened or slightly concave transversely near the base. In nearly all cases this surface slopes towards the dorsal border, just as the internal cuneiform facet slopes towards the plantar. The direction of this surface would make the posterior aspect of the middle cuneiform look somewhat downwards, and hence the anterior aspect of the same bone look somewhat upwards. This was probably correlated with more freedom of movement of the second toe in an extensor direction, which would be expected in a race not compressing their feet artificially.

In many of those specimens where the above shelving away was pronounced there was a well-marked lipping of the bone at the junction of the dorsal and anterior surfaces, *i.e.* at the border of the base of the wedge. It is true that in some of these cases the bone was the subject of osteo-arthritis, but there were many instances where the bone had been apparently healthy. There is a distinct and direct relationship between this shelving away and the lipping of the bone in this situation.

Articulatio Cuneo-navicularis III.

The Facet for the External Cuneiform. (Figs. 10, 11, and 12.)

In most cases (239) this facet has the shape of a very blunt wedge with the narrow end of the wedge pointing towards the cuboidal facet; in 59 cases it points towards the plantar surface.

In 189 cases this facet is four-sided, in two pentagonal; with rounded angles near the cuboidal facet in both varieties. This surface is either flattened or concave. It was slightly concave and four-sided in 53 specimens. In a few, markedly concave; see diagram (fig. 12).

When the concavity is well marked and this facet is four-sided, we have the anthropoid type of articular surface in this situation. It is especially well marked in the gorilla, but is present in all the Simiidæ (figs. 10 and 11).

Direction of this surface.—It shelves away considerably in nearly all cases towards the lateral and dorsal surfaces, so that it looks rather more outwards and upwards than in modern bones. The outward direction would have the effect of throwing the long axis of the external cuneiform, and through this the middle metatarsal bone, outwards. The upward direction would have the effect of throwing the posterior surface of the external cuneiform downwards, the anterior surface, and with it the third metatarsal bone, upwards. This is probably correlated with greater freedom of extension and abduction of the middle toe.

Facies Dorsalis Superior.

This is that part of the so-called superior or dorsal surface of English text-books which looks upwards and outwards.

The most interesting point in connection with this surface is the presence, in some cases, of a groove which runs obliquely forwards and inwards. It was present in 65 specimens. The depth of the groove is variable; it must not be confused with another groove which is occasionally present and runs in the opposite direction—forwards and outwards. The first of the two grooves is for the attachment of ligaments, namely, the lateral (external) astragalo-navicular and the dorsal cubo-navicular ligaments. The second is probably for the tarsal branch of dorsalis pedis artery. This artery, however, is so variable in its origin and course, that I was not able to satisfy myself that the occasional groove was a vascular one. A third groove may be present, at the junction of the facies dorsalis superior and the facies lateralis, and close to the articulatio cubo-navicularis when that articulation is present. This is for the attachment of the external calcaneo-navicular ligament.

Facies Dorsalis Medialis.

This is that part of the so-called superior or dorsal surface of English text-books which looks upwards and inwards.

A ridge is present in many of the specimens (363) on this surface, about one-sixth of an inch from the margo dorsalis anterior, and parallel to it; between the ridge and the margin is a narrow groove in most of the above (363) specimens. This ridge and groove are for the attachment of the ligaments connecting this bone with the cuneiform bones.

In some cases, the above-mentioned ridge is broken by a slight depression opposite the middle cuneiform. This depression is in the position of the dorsalis pedis artery. I could not be certain, however, from

an examination of recent specimens, that the dorsalis pedis artery indented the bone here.

In many cases (238), there is a second ridge one-sixth of an inch from the margo dorsalis posterior. It bounds anteriorly a slight groove situated between the ridge and the margin. This ridge and groove are for the ligaments connecting the navicular with the talus.

In some cases there is a third shallow groove or depression placed between the two ridges, and midway between the margo dorsalis anterior and posterior.

Facies Lateralis.

This extends from the facies dorsalis superior to the facies plantaris. It is described in English text-books as the external surface, but it looks almost as much downwards as outwards. It is rough in most of its extent. Its chief points of interest are: (*a*) the frequent presence of a facet for the cuboid; (*b*) an occasional facet for the os calcis; (*c*) a small tubercle, the plantar point, which has already been described.

Articulatio Cubo-navicularis. (Figs. 15 to 18.)

The cuboid facet is situated at the junction of the facies articularis anterior and facies lateralis. It is present in 332 specimens, or about 70 per cent. of those examined with reference to this surface.

Pfitzner found a distinct joint here in 50·4 per cent., Gruber in 45·5 per cent. According to him, it is more frequent in the female than in the male. Of the 332 specimens in which I found it, 163 out of 274 examined belonged to the right, and 168 out of 260 examined to the left side. In my specimens, therefore, it appeared to be rather more frequent on the left side. Its shape is somewhat variable; in most cases it is four-sided, with the posterior angles rounded off (fig. 15). In some of these it is almost square (54), in others oblong (4). In some cases (142) it is wedge-shaped, with the base of the wedge directed anteriorly (fig. 16). In a few it was semilunar (4) or rhomboidal (4). In all cases the border which separates it from the facet for the external cuneiform is sharp and well marked. The facet varies in size from a threepenny piece to a large pin's head. There is nearly always a rough interval, which is generally depressed or grooved, between this facet and that for the caput tali. In some instances the cuboid facet nearly approaches the facet for the caput tali, and occasionally quite reaches it, extending from the articulatio cuneo-navicularis III. to the facies articularis posterior. Not infrequently the facet extends on to the plantar point (fig. 17). Pfitzner would regard these cases as due to extension of the cubo-navicular joint to a cuboides secundarium.

Some additional evidence against his view is gathered from the fact that the cubo-navicular joint extends on to the plantar point in the

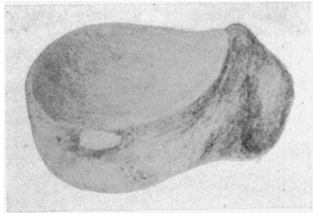

FIG. 13.

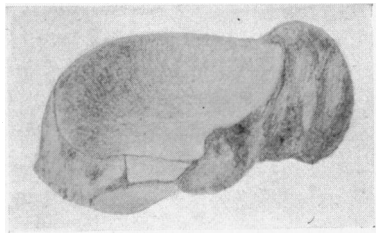

FIG. 14.

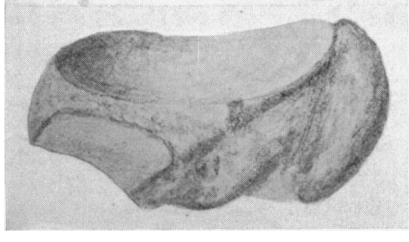

FIG. 15.

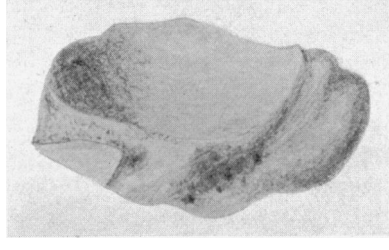

FIG. 16.

FIG. 17.—Man.

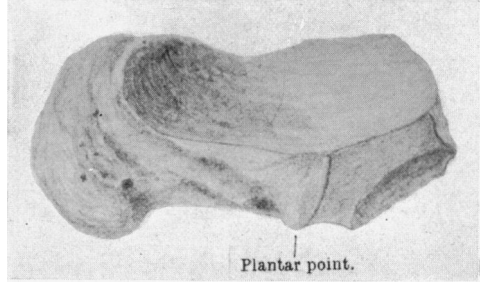

FIG. 18.—Chimpanzee.

FIGS. 13 and 14 show occasional facet for os calcis. FIGS. 15 and 16 show quadrilateral and wedge-shaped facets for cuboid. FIGS. 17 and 18, extension of the cuboidal facet on to the plantar point in man and the chimpanzee. FIG. 18 also shows that the concavity for caput tali is almost entirely in the long diameter in the chimpanzee. This is so in all the Simiidæ.

Simiidæ, in which this process is generally insignificant, does not project towards the astragalar surface, and does not give a cuboidal outline to the bone (fig. 18).

Articulatio Calcaneo-navicularis. (Figs. 13 and 14.)

This occasional facet for the os calcis is present in 13 specimens, 8 right and 5 left. The facet is close to the surface for caput tali, between the cuboidal facet and the plantar point. Its shape varies slightly: in two cases it was rhomboidal, in one triangular, in one oblong and in one wedge-shaped; in three cases there was a fairly sharp ridge separating it from the cuboidal facet. Pfitzner found this articulation in 8 specimens. The presence of this articulation is due, according to Pfitzner, to the existence of a rudimentary calcaneus secundarius which has fused with the os calcis.

Facies Plantaris.

By this is meant that surface between the plantar point and the tuberositas ossis navicularis It is directed downwards. It presents many foramina for nutrient vessels. In most cases it is marked by an oblique groove, situated at the junction of the tuberosity with the body of the bone. This groove commences posteriorly between the tuberosity and the facet for the caput tali, and runs obliquely forwards and outwards along the plantar surface, to terminate at the margo-plantaris anterior. The groove varies in depth in different specimens; in some cases it is almost as deep as the groove on the cuboid for the peroneus longus tendon. The groove occupies the greater part of the inferior surface. It lodges that portion of the tibialis posticus tendon which passes to the metatarsal bones

Tuberositas Ossis Navicularis.

This may be considered, from a descriptive point of view, under size, prominence, and shape, and from a morphological, embracing the embryology of the tuberosity, its components and their nature.

Description.—In the following account I have included as tuberosity that portion of the whole navicular which projects mesially and plantarwards, beyond a line drawn round the bone from the tibio-plantar angle (apex of pear-shaped facet for caput tali) to the apex of the facet for the internal cuneiform.

Size.—This may be discussed under (*a*) the absolute size of the tuberosity; (*b*) the size of the tuberosity compared with the size of the corpus.

(*a*) The tuberosity in some cases is extremely large, in others almost absent. Its size depends partly upon the number of morphological elements which it contains, and partly on the traction exerted on it during life by the tibialis posticus muscle.

(*b*) In some few cases, a large bone had a large tuberosity; there is no direct relationship, however, in most cases, between the size of the corpus and tuberosity, for whilst some of the smaller bones have a well-developed process, forming, occasionally, one-third of the whole bone, in some of the larger the tuberosity is insignificant. This would be expected from the morphology of the tuberosity.

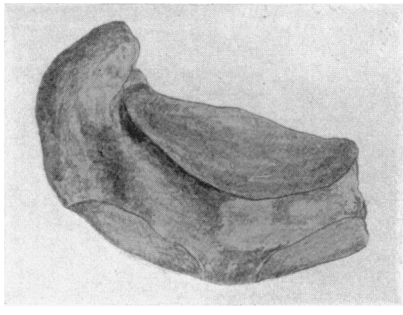

FIG. 19.

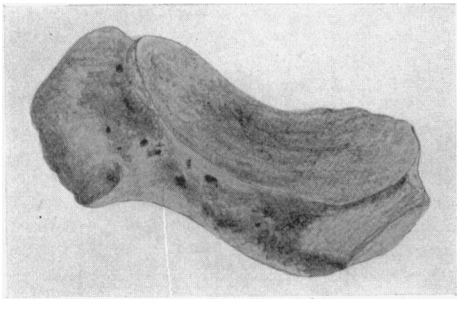

FIG. 20.

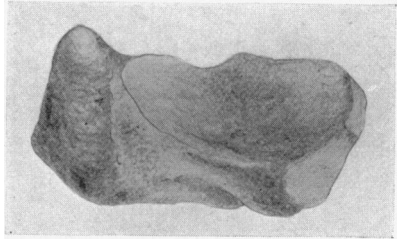

FIG. 21.

FIG. 19 shows the elongated type of tuberosity in man. Figs. 20 and 21, the tuberosities as they exist in the gorilla and chimpanzee; figs. 20 and 21 also show that the concavity of the surface for caput tali is in the long diameter in these animals.

Shape.—With reference to shape, there are two chief types of tuberosity.

(1) In most cases (345) the tuberosity is a somewhat four-sided prism with the angles rounded off. Of the 345, 173 belonged to the right side, 172 to the left. In these cases the tuberosity possesses the following surfaces:—

A facies anterior, which is continuous with the facies articularis anterior of the body. It is frequently marked by a slight groove for a ligament between the tuberosity and the internal cuneiform.

A facies dorsalis, which is continuous with the facies dorsalis medialis of the body. It has often a depressed cribriform area for nutrient vessels.

A facies plantaris lateralis, which is continuous with the facies plantaris of the body.

A facies plantaris inferior, joining the last two surfaces. In some cases this surface is very small or non-existent, the facies dorsalis and plantaris lateralis meeting here in a ridge or nipple-like process

(2) The other type of process is the elongated. This occurred in 109 cases out of 454 examined with reference to the tuberosity, or about 25 per cent. It occurs with rather greater frequency on the right side than on the left, thus :—

In 239 right it occurred in 66 cases, or about 28 per cent.
„ 215 left „ „ 43 „ „ 20 „

In the elongated type of tuberosity the facies anterior is non-existent as a distinct surface, and shelves away into the facies plantaris inferior. In addition, the apex of the bone is produced proximally, and generally terminates in this direction in a nipple-like manner. It is this variety which may carry the abnormal surface, facies articularis tuberositatis, for the caput tali.

The manner of production of these two types of tuberosity will be mentioned later.

The apex of the tuberosity may occupy three situations :—

(*a*) It may be situated at a small tubercle close to and dorsalwards of the tibio-plantar angle (apex of pear-shaped astragalar facet). This may be called the apophysial apex.

(*b*) It may be situated a line or two on the distal side of and plantarwards of the above tubercle. This may be called the epiphysial apex.

(*c*) It may be produced proximally, so as to occupy a position $\frac{1}{8}$ to $\frac{1}{4}$ of an inch posterior to the above tubercle. This may be called the sesamoid apex.

Ossification.

Anatomists are agreed that the navicular is ossified as a rule from a centre which is situated in the body and appears between the third and the sixth year—to be more exact, according to most British anatomists and to Béclard, between the fourth and fifth years, and according to Rambaud and Renault, at the age of from four and a half to five and a half years.

The occurrence of the process of the navicular tuberosity as an exceptional epiphysis, or later as an articulating ossicle, cannot therefore, as

Gruber states, be explained from the usual course of development. It will be discussed under the next heading.

Morphology.

The portion of bone included in the above description as tuberosity will be found to consist of a variable number of elements of different morphological value. The evidence derived from those abnormal cases in which a separate ossicle is found in this situation would suggest that the whole tuberosity is made up of one, two, or in some cases three components:—

(*a*) A portion near the corpus which is merely an apophysis of that body. From this the whole of the facies anterior and facies dorsalis and facies articularis are formed, together with a little tubercle at the upper part of the latter surface and close to the tibio-plantar angle (apex of the pear-shaped facet for caput tali).

This apophysial element is a distinctly wedge-shaped portion of bone, with its base at the facies anterior and its apex (apophysial apex) at the above-mentioned tubercle near the tibio-plantar angle. Its surface for articulation (facies articularis) or coalescence with the epiphysial part of the tuberosity is slightly concave, and has an oval, quadrilateral, or circular outline, and is rough for the junction of the epiphysial portion of the tuberosity (fig. 24). It has generally a raised margin. If the epiphysial portion is absent, the so-called facies articularis forms the free facies plantaris lateralis.

(*b*) The epiphysial portion, corresponding apparently to the naviculare secundarium of Gruber. The part formed from the epiphysis is either prismatic or oval in shape, the exact shape depending on the presence or absence of a third element of the tuberosity. In the prismatic type it possesses four surfaces—a facies articularis which fuses or articulates with the facies articularis of the apophysial portion; two surfaces which form most of the facies plantaris lateralis and facies plantaris inferior of the tuberosity; and lastly, the base of the prism, which is directed backwards in the natural position of the bone. This is more or less concave, and receives the base of the third element of the tuberosity with which it fuses. In the oval type the epiphysial portion is a mere lamina of bone.

(*c*) The last and most variable element of the tuberosity is the so-called sesamoid bone in the tendon of the tibialis posticus, which may fuse with the tuberosity. When it is present it produces the tuberosity proximally, and is somewhat pea-like in shape, resembling closely the human pisiform bone (fig. 26). It is the presence of this element which gives rise to the elongated type of tuberosity described earlier; with its absence we have the prismatic

type. When this element is present there is not infrequently an extension

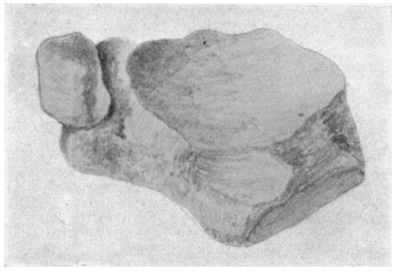

FIG. 22.

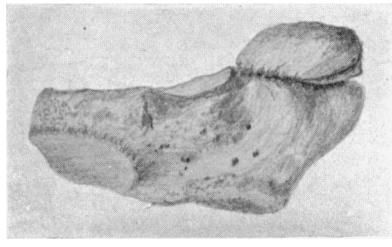

FIG. 23.

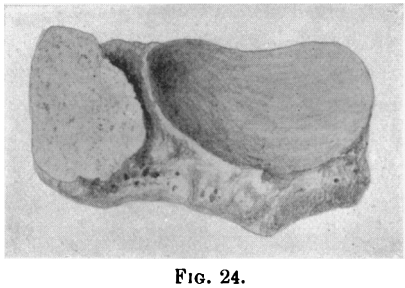

FIG. 24.

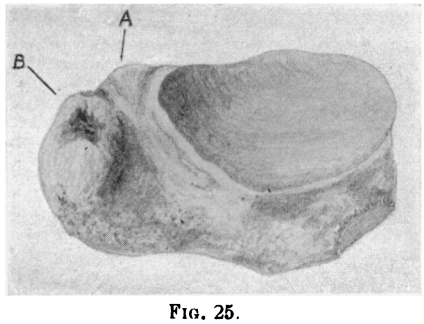

FIG. 25.

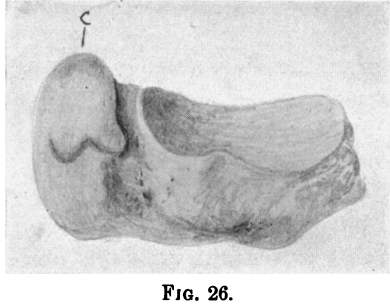

FIG. 26.

Figs. 22 and 23 show separate ossicles, and there is a tendency to subdivision in fig. 23. In fig. 24, the whole ossicle has disappeared; the surface with raised margins is the facies articularis of the apophysial portion, for articulation or coalescence with the epiphysial portion. In fig. 25 the sesamoid element only has disappeared; the epiphysial element remains, and presents a concave surface for coalescence or articulation with the sesamoid portion. In fig. 26 the ossicle has fused; its line of junction can, however, be seen. A, apophysial apex; B, epiphysial apex; C, sesamoid apex.

of the surface for caput tali on to the tuberosity (facies articularis tuberositatis).

The single bone which Pfitzner describes as tibiale externum corresponds in shape and position to the parts described above under (*b*) and (*c*). It is true that we only get a single separate ossicle in this position. In one of my specimens (fig. 23), however, the ossicle was imperfectly bipartite, and Pfitzner mentions five cases in which it was in the same condition. This would suggest the view that the single ossicle may consist of both of the above-mentioned elements (*b*) and (*c*) fused. It may be conjectured from the shape of the articular surfaces, or from the lines of coalescence, which element is missing, as shown in the accompanying diagrams (figs. 24 and 25).

Gruber mentions a case where there was an element apparently corresponding to my epiphysial portion, which he calls naviculare secundarium. It was *coalesced* in the foot of one side and *ankylosed* on the other. He also depicts a navicular with a large migrated sesamoid, and which he cautions us against confusing with the above-mentioned naviculare secundarium.

Although, as Pfitzner maintained, the sesamoid bone in the tibialis posticus (tibiale externum, Pfitzner) may fuse and form part of the tuberosity, it probably only forms the proximal portion of the tuberosity, and the occasional bipartite condition of the ossicle found here, together with the shape of the surfaces of articulation or coalescence, would suggest that there is another element between this sesamoid element and the apophysial part of the tuberosity, namely, that which I have described as the epiphysial portion. Bardeleben has shown that there is a separate cartilage at the tuberosity up to the second month of fœtal life. Pfitzner, however, apparently would claim this cartilage as the same element as his tibiale externum. The matter can only be settled by the examination of a large number of young tarsal bones varying in age, preferably from the fifth to the twenty-fifth year.

The Os Naviculare in Anthropoid Apes. (Figs. 10, 11, 18, 20, and 21.)

ANTHROPOIDEA. SIMIIDÆ.

GORILLA.

Facies Posterior.

The outline of the surface more nearly approaches an oval than in any of the other Simiidæ, but is really shoe-shaped in outline, with the heel of the shoe directed downwards and inwards.

Depth of concavity.—It is deeply concave in the long diameter, the

two ends projecting backwards about equally. There is no great depth of concavity in the shorter diameter. The plantar point is present, but does not encroach upon this surface, being separated from it by about one-fourth of an inch.

Facies Anterior.

The general outline of this surface is semilunar.

Articulatio cuneo-navicularis I.—This is wedge-shaped, and very like that variety in man which shelves away towards the plantar surface and tuberosity.

Articulatio cuneo-navicularis II.—This is also wedge-shaped, and shelves away towards the dorsum in a similar way to that existing in the human subject (ancient bones).

Articulatio cuneo-navicularis III.—Quadrilateral in shape and deeply concave, its concavity suggesting the articulation between the os magnum and the scaphoid.

Facies Lateralis.

Articulatio cubo-navicularis.—This facet forms an oblong figure extending from the facies dorsalis superior to the plantar point.

Facies Dorsalis Superior.

This is wedge-like in outline. It has a groove near and parallel to the margo dorsalis anterior.

Facies Dorsalis Medialis.

This is marked about the middle by a well-developed ridge which commences in a tubercle superiorly. The ridge separates two grooves which are situated respectively between it and the margo dorsalis anterior and the margo dorsalis posterior.

Facies Plantaris.

The groove is present, separating the tuberositas ossis navicularis from the os naviculare, as in the human subject.

Tuberositas Ossis Navicularis.

This is of the elongated type.

ANTHROPOPITHECUS TROGLODYTES.

Facies Posterior.

This surface is pear-shaped, and deeply concave in the long diameter. The plantar point is small, and does not project towards or encroach upon this surface, but helps to support the cuboidal facet.

Facies Anterior.

Articulatio cuneo-navicularis I.—This is wedge-shaped, and shelves away considerably towards the plantar surface.

Articulatio cuneo-navicularis II.—This facet shelves away considerably towards the dorsal surface—much more so than in the human subject.

Articulatio cuneo-navicularis III.—This is a quadrilateral facet, and is deeply concave.

Facies Dorsalis Superior.

Very small in extent: not grooved.

Facies Dorsalis Medialis.

There is a well-marked ridge on this surface, which corresponds to that ridge in the human subject which is near the margo dorsalis anterior; there is a depression behind it close to the facies posterior.

Facies Plantaris.

There is a very narrow oblique groove between the body and tuberosity.

Facies Lateralis.

Articulatio cubo-navicularis.—The articulation occupies the whole of the surface and encroaches upon the plantar point.

Tuberositas Ossis Navicularis.

This is four-sided: the apex is somewhat blunt.

SIMIA SATYRUS.

Facies Posterior.

In shape it is almost oval. It is deeply concave in the long diameter. The plantar point does not encroach upon this surface.

Facies Anterior.

Articulatio cuneo-navicularis I.—This facet is wedge-shaped, and does not shelve away towards the plantar or dorsal surfaces. It shelves away towards the tuberosity.

Articulatio cuneo-navicularis II.—This part slopes away considerably towards the dorsal surface.

Articulatio cuneo-navicularis III.—This is quadrilateral in shape and is deeply concave, as in the gorilla and chimpanzee. It looks forwards and outwards.

Facies Dorsalis Superior.

Oblong in shape: possesses a slight groove near the margo dorsalis anterior.

Facies Dorsalis Medialis.

Possesses a slight ridge separating two grooves, as in the gorilla.

Facies Plantaris.

There is no groove on this surface between the body of the bone and the tuberosity, as in the gorilla.

Facies Lateralis.

Articulatio cubo-navicularis.—This facet is somewhat wedge-shaped, with the broad end of the wedge supported by the plantar point.

Tuberositas Ossis Navicularis.

In this family the tuberosity is either small or non-existent.

HYLOBATES.

Facies Posterior.

Oval in shape and deeply concave in the long diameter, in consequence of the projection of the tuberosity backwards and upwards. The tuberosity therefore helps to support the head of the astragalus.

Facies Anterior.

Articulatio cuneo-navicularis I and II. are flatter than in the other anthropoid apes examined.

Articulatio cuneo-navicularis III. is slightly concave and somewhat wedge-shaped.

Facies Dorsalis Superior.

Oblong and smooth.

Facies Dorsalis Medialis.

There is a slight concavity crossing the bone, from the margo dorsalis anterior to the margo dorsalis posterior.

Facies Plantaris.

There is no oblique groove on this surface.

Tuberositas Ossis Navicularis.

The tuberosity, though small, is prolonged proximally, and helps to support the head of the astragalus.

Summary of the most Interesting Particulars observed in the Specimens examined.

(1) The variability in shape and the two types of concavity of the facies articularis posterior.

(2) The encroachment of the plantar point on this surface, and its projection upwards and backwards beneath the caput tali.

(3) The presence of a faint suture between the astragalar surface of plantar point and the rest of the navicular surface for caput tali, in one specimen.

(4) The plantar point appears to be better developed in these bones than in modern specimens. This is probably correlated with a higher tarsal arch.

(5) Increase of concavity, in the long diameter, of the facies articularis posterior, is probably correlated with freedom of movement at this joint.

(6) The two types of surfaces at the articulatio cuneo-navicularis I., *i.e.* the flattened and the ridged.

(7) The shelving away of the surface for articulatio cuneo-navicularis II. towards the margo dorsalis anterior.

(8) The great shelving away of the surface for articulatio cuneo-navicularis III. towards the facies lateralis.

(9) The frequent presence of a quadrilateral and concave surface at articulatio cuneo-navicularis III., as in the Simiidæ.

(10) The grooves on the facies dorsalis superior.

(11) The two ridges and grooves for ligaments on the facies dorsalis medialis.

(12) The frequent presence (70 per cent.) of the articulatio cubo-navicularis.

(13) The extension of articulatio cubo-navicularis on to plantar point in some cases.

(14) In one of the above cases there was a slight gap between the part of the cuboidal facet contributed by the plantar point and that contributed by the rest of the navicular.

(15) The occasional presence of an articulatio calcaneo-navicularis.

(16) The existence of the tuberosity as a separate ossicle in some cases, and the shape of the articulating or coalescing surfaces.

(17) Evidence suggesting that the tuberosity consists of three elements in many cases—an apophysial, an epiphysial, and a sesamoid.

(18) The two types of tuberosity, the prismatic and the elongated, these being dependent upon the morphological elements which the tuberosity contains.

(19) The occasional presence of a facet for caput tali on the posterior and outer surface of the proximal part of the tuberosity (facies articularis tuberositatis).

(20) The fact that the concavity of the facet for caput tali in anthropoid apes is chiefly in the long diameter.

(21) The quadrilateral concave surface of articulatio cuneo-navicularis III. in the same animals.

(22) The small size of the plantar point in all the Simiidæ, its non-encroachment on the astragalar surface, and the fact that it often supports the articulatio cubo-navicularis.

From the above summary it is evident that the navicular bone offers many interesting points for our notice. Some of these characteristics are mainly of morphological import, such as the number of elements included in the tuberosity, the occasional existence here of a separate ossicle, the nature of this ossicle and its relationship to Pfitzner's tibiale externum.

Others are suggestive of a mechanical significance—for instance, the shelving of the cuneiform surfaces, which is apparently more marked in these Egyptian bones than in modern specimens. This was probably correlated with greater freedom of movement of the digits, which in turn was no doubt dependent upon the fact that the feet of these ancient people were not compressed artificially.

The plantar point is probably dependent on traction or a traction outgrowth, unless we adopt Pfitzner's view and regard it as the representative of a separate tarsal element. It has also a purely mechanical function, supporting the arch of the foot in a bracket-like manner.

Lastly, certain features are of both morphological and mechanical

interest, such as the shape of the articulation for the caput tali, and the nature, direction, and depth of this concavity in man and the Simiidæ: all of these characteristics being correlated with the extent and variety of movement at the transverse tarsal joint, in man and the anthropoid apes.

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